



#176: Macintosh Memory Configurations

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This Technical Note describes the different possible memory configurations of all models of the Macintosh family that use Single In-line Memory Modules (SIMMs) as well as the non-SIMM memory upgrade options of the Macintosh Portable and Macintosh Classic. (Special thanks to Brian Howard for the Macintosh Plus and original SE drawings, and for the inspiration for the other drawings.) This Note also describes the obstacles to using four megabit (Mbit) DRAM SIMMs in Apple's Macintosh products to date.

Changes since June 1990: Added Macintosh Classic, LC, and IIsi configurations.

Developer Technical Support receives numerous questions about the many different possible configurations of RAM on the different Macintoshes, so we'll attempt to answer these questions in this Technical Note, as well as to provide a showcase for some outstanding artwork by Apple engineer Brian Howard. Interested readers should refer to the *Guide to the Macintosh Family Hardware*, Second Edition, which contains much more detail on the memory configurations and specifications for all Macintosh models released to date.

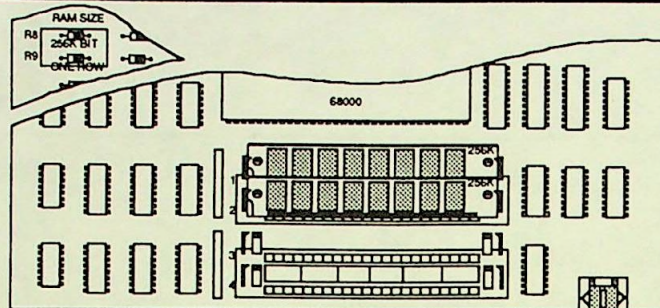
Warning: Because the video monitor is built in, there are dangerous voltages inside the cases of the Macintosh Plus, SE, Classic, and SE/30 computers. The video tube and video circuitry may hold dangerous charges long after the computer's power is turned off. Opening the case of these computers requires special tools and may invalidate your warranty. Installation of RAM in the SIMM sockets in these computers should be done by qualified service personnel only.

Macintosh Plus

The Macintosh Plus has the following possible configurations (see Figure 1):

- 512K, using two 256 Kbit SIMMs
- 1 MB, using four 256 Kbit SIMMs
- 2 MB, using two 1 Mbit SIMMs
- 2.5 MB, using two 1 Mbit SIMMs and two 256 Kbit SIMMs
- 4MB, using four 1 Mbit SIMMs

It is important to place the SIMMs in the correct location when using a combination of SIMM sizes, as in the 2.5 MB example, and to make sure the right resistors are cut. Refer to Figure 1 for the correct location of the SIMMs and size resistors.



System Memory Size: 512K

SIMMs Configuration

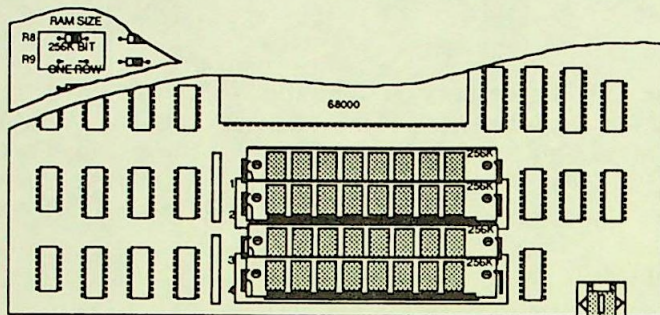
Row 1 (SIMMs 1 & 2): 256K

Row 2 (SIMMs 3 & 4): Not Installed

RAM SIZE Resistors

256 Kbit (R8): 150 Ohms

One Row (R9): 150 Ohms



System Memory Size: 1 MB

SIMMs Configuration

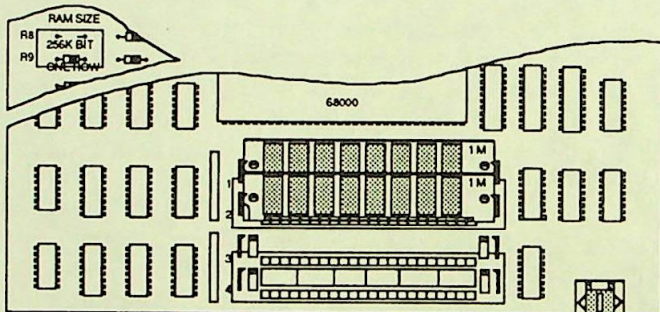
Row 1 (SIMMs 1 & 2): 256K

Row 2 (SIMMs 3 & 4): 256K

RAM SIZE Resistors

256 Kbit (R8): 150 Ohms

One Row (R9): Not Installed



System Memory Size: 2 MB

SIMMs Configuration

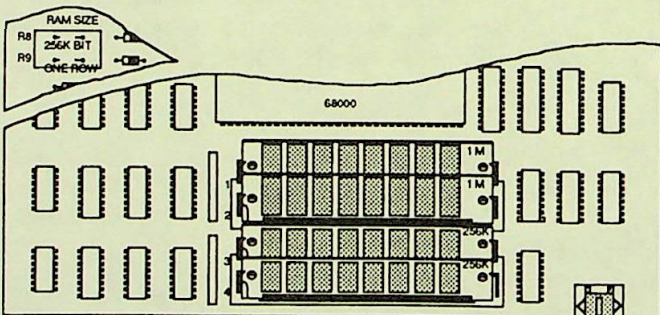
Row 1 (SIMMs 1 & 2): 1 MB

Row 2 (SIMMs 3 & 4): Not Installed

RAM SIZE Resistors

256 Kbit (R8): Not Installed

One Row (R9): 150 Ohms



System Memory Size: 2.5 MB

SIMMs Configuration

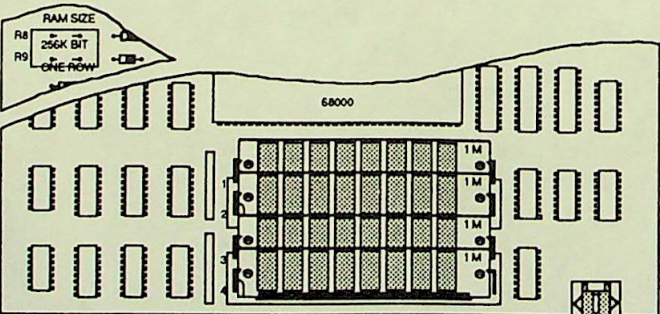
Row 1 (SIMMs 1 & 2): 1 MB

Row 2 (SIMMs 3 & 4): 256K

RAM SIZE Resistors

256 Kbit (R8): Not Installed

One Row (R9): Not Installed



System Memory Size: 4 MB

SIMMs Configuration

Row 1 (SIMMs 1 & 2): 1 MB

Row 2 (SIMMs 3 & 4): 1 MB

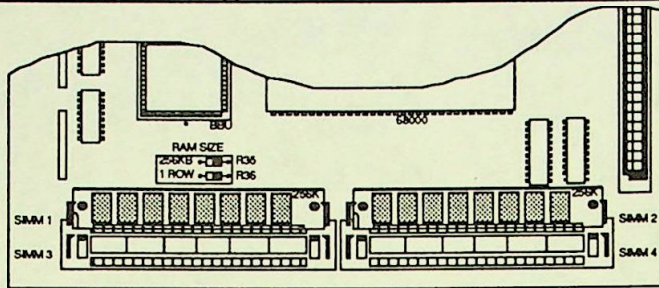
RAM SIZE Resistors

256 Kbit (R8): Not Installed

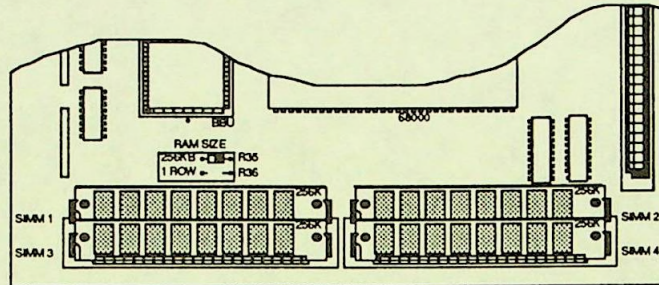
One Row (R9): Not Installed

(SIMMs must be 150 nS RAS-access time or faster, and the same speed within a row.)

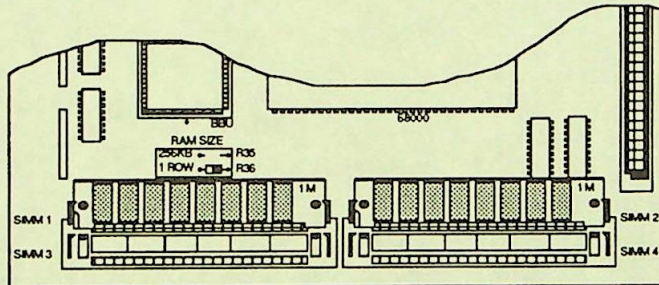
Figure 1—Macintosh Plus Memory Configurations



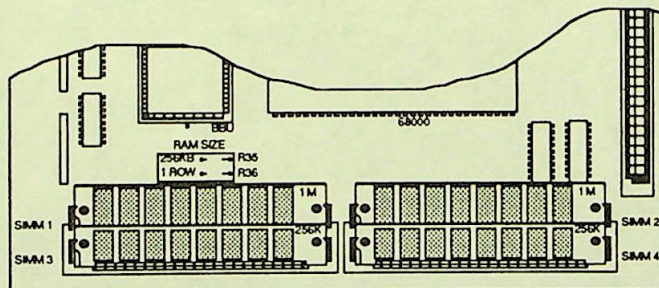
System Memory Size	512K
SIMMs Configuration	
Row 1 (SIMMs 1 & 2)	256K
Row 2 (SIMMs 3 & 4)	Not Installed
RAM SIZE Resistors	
256 Kbit (R35)	150 Ohms
One Row (R36)	150 Ohms



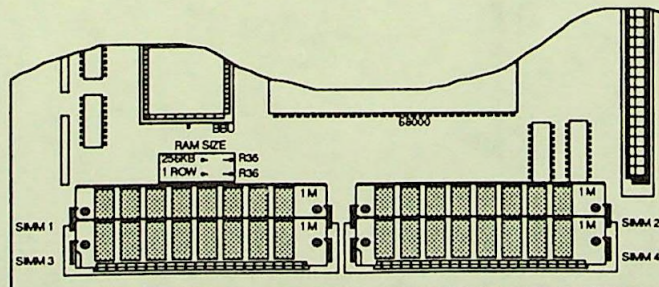
System Memory Size	1 MB
SIMMs Configuration	
Row 1 (SIMMs 1 & 2)	256K
Row 2 (SIMMs 3 & 4)	256K
RAM SIZE Resistors	
256 Kbit (R35)	150 Ohms
One Row (R36)	Not Installed



System Memory Size	2 MB
SIMMs Configuration	
Row 1 (SIMMs 1 & 2)	1 MB
Row 2 (SIMMs 3 & 4)	Not Installed
RAM SIZE Resistors	
256 Kbit (R35)	Not Installed
One Row (R36)	150 Ohms



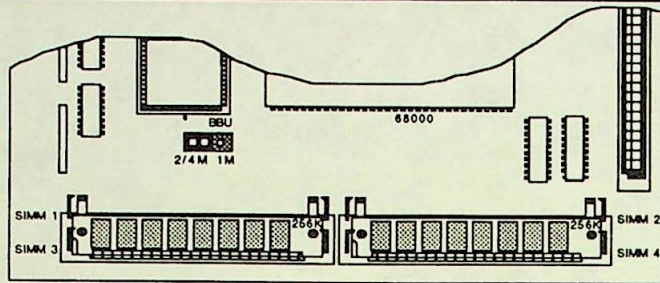
System Memory Size	2.5 MB
SIMMs Configuration	
Row 1 (SIMMs 1 & 2)	1 MB
Row 2 (SIMMs 3 & 4)	256K
RAM SIZE Resistors	
256 Kbit (R35)	Not Installed
One Row (R36)	Not Installed



System Memory Size	4 MB
SIMMs Configuration	
Row 1 (SIMMs 1 & 2)	1 MB
Row 2 (SIMMs 3 & 4)	1 MB
RAM SIZE Resistors	
256 Kbit (R35)	Not Installed
One Row (R36)	Not Installed

(SIMMs must be 150 nS RAS-access time or faster, and the same speed within a row.)

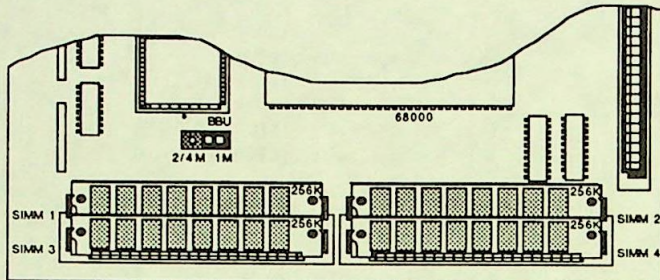
Figure 2—Macintosh SE Memory Configurations



System Memory Size 512K

SIMMs Configuration
 Row 1 (SIMMs 1 & 2): Not Installed
 Row 2 (SIMMs 3 & 4): 256 K

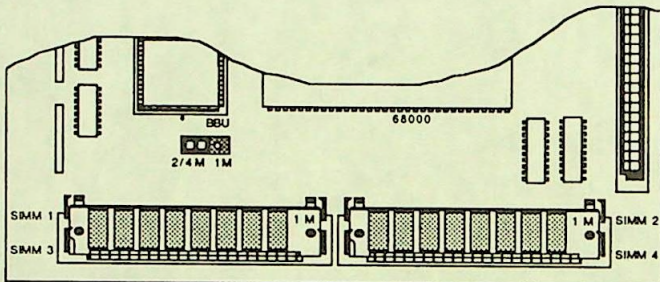
Jumper on 2/4M



System Memory Size 1 MB

SIMMs Configuration
 Row 1 (SIMMs 1 & 2): 256 K
 Row 2 (SIMMs 3 & 4): 256 K

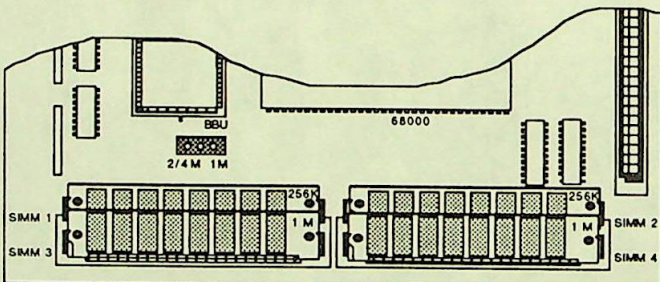
Jumper on 1M



System Memory Size 2 MB

SIMMs Configuration
 Row 1 (SIMMs 1 & 2): Not Installed
 Row 2 (SIMMs 3 & 4): 1 MB

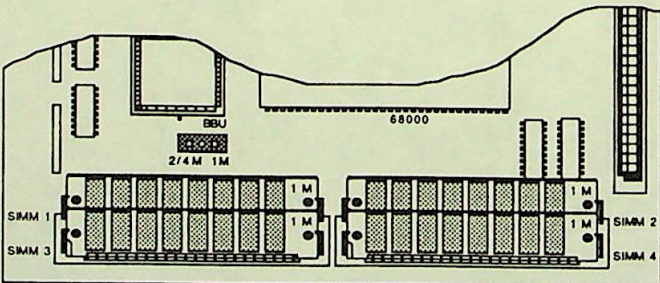
Jumper on 2/4M



System Memory Size 2.5 MB

SIMMs Configuration
 Row 1 (SIMMs 1 & 2): 256K
 Row 2 (SIMMs 3 & 4): 1 MB

Jumper off



System Memory Size 4 MB

SIMMs Configuration
 Row 1 (SIMMs 1 & 2): 1 MB
 Row 2 (SIMMs 3 & 4): 1 MB

Jumper off

(SIMMs must be 150 nS RAS-access time or faster, and the same speed within a row.)

Figure 3—Macintosh SE (with jumper) Memory Configurations

Macintosh SE

The Macintosh SE configurations (the original motherboard as well as the revised motherboard with a memory jumper selector) are the same as the Macintosh Plus, except physical locations on the motherboard are different. In addition, memory configurations with only two SIMMs (e.g., 512K and 2 MB) use slots 3 and 4 on the revised SE motherboard instead of slots 1 and 2 like the original motherboard and Macintosh Plus. Refer to Figures 2 and 3 for the correct locations and settings.

Macintosh Classic

The Macintosh Classic has the following possible configurations (see Figure 4).

- 1 MB, using eight 128 Kbit DRAMs soldered to the motherboard
- 2 MB, using the memory expansion card and setting the jumper to "SIMM NOT INSTALLED"
- 2.5 MB, using two 256 Kbit SIMMs on the memory expansion card and setting the jumper to "SIMM INSTALLED"
- 4 MB, using two 1 Mbit SIMMs on the memory expansion card and setting the jumper to "SIMM INSTALLED"

When adding SIMMs to the memory expansion card, use either two 256 Kbit or two 1 Mbit parts rated at 120 ns or faster.

Macintosh SE/30, II, IIx, and IICx

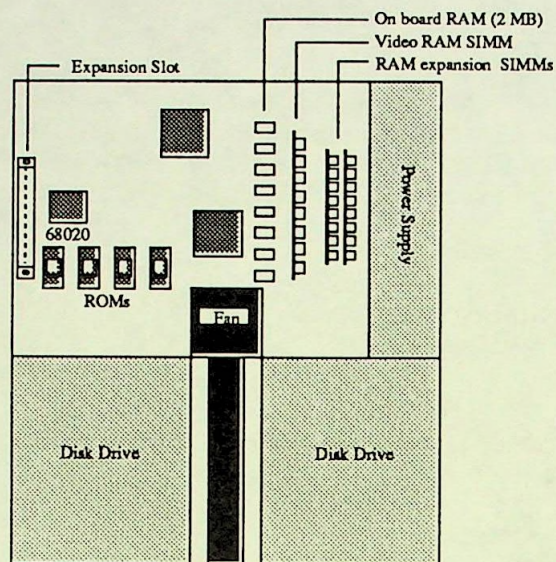
Since these machines use a 32-bit data bus with eight-bit SIMMs, you must always upgrade memory in four SIMM chunks. The eight SIMM connectors are divided into two banks of four SIMM slots, Bank A and Bank B.

On the Macintosh SE/30, Bank A is located next to the ROM SIMM while Bank B is next to the 68882 co-processor. On the Macintosh II and IIx, Bank A is the bank closest to the edge of the board, while on the Macintosh IICx, Bank A is the bank closest to the disk drives and power supply. Refer to Figure 5 for the proper locations of Banks A and B on the SE/30, II, and IIx, and refer to Figure 6 for the proper locations on the IICx.

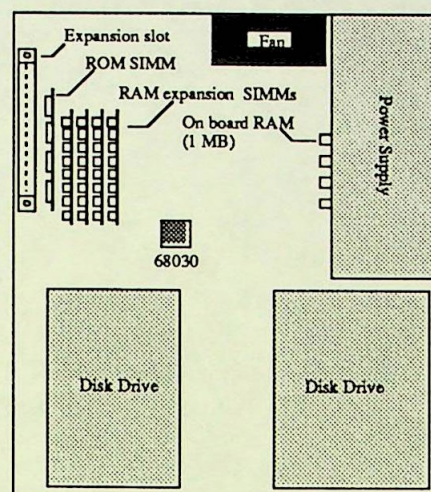
Unlike the Macintosh Plus and the Macintosh SE, these machines have no resistors to cut and no jumpers to set; you need only install the SIMMs in the correct banks and you'll be up and running. You can implement the following configurations:

- 1MB, using four 256 Kbit SIMMs in Bank A
- 2MB, using eight 256 Kbit SIMMs in Banks A and B
- 4MB, using four 1 Mbit SIMMs in Bank A
- 5MB, using four 1 Mbit SIMMs in Bank A and four 256 Kbit SIMMs in Bank B
- 8MB, using eight 1 Mbit SIMMs in Banks A and B

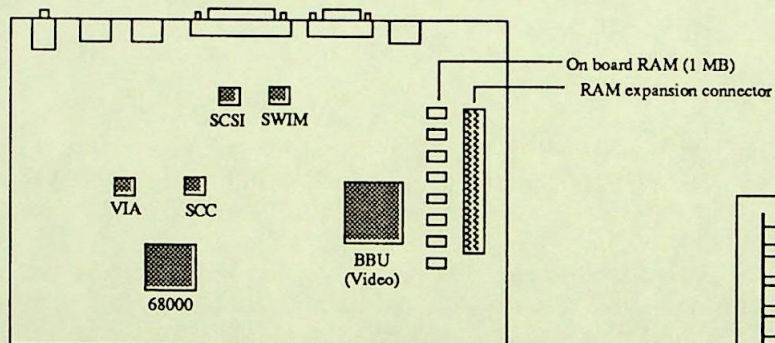
Again, it is important to make sure the right size SIMMs are in the right Bank; when you are using a combination of SIMMs, the larger SIMMs (in terms of Mbits) must be in Bank A. When you are using only four SIMMs, they must be in Bank A as well.



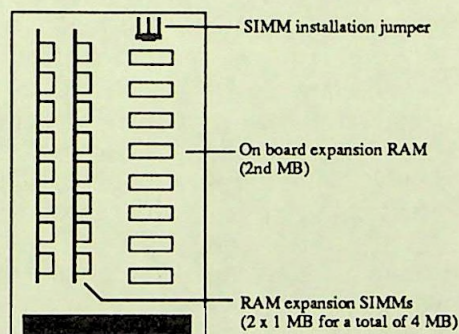
Macintosh LC
(RAM SIMMs must be 100 nS RAS-access time or faster.)



Macintosh IIx
(SIMMs must be 100 nS RAS-access time or faster.)



Macintosh Classic
(SIMMs must be 120 nS RAS-access time or faster.)



Macintosh Classic RAM expansion board

Figure 4—Macintosh Classic, LC, and IIx

Macintosh LC

The Macintosh LC uses a 16-bit data bus with 8-bit SIMMs, so upgrades must always be performed two SIMMs at a time. The LC has two SIMM connectors which are used as a single additional RAM bank (see Figure 4) in addition to the 2 MB already soldered to the motherboard. The following memory configurations can be implemented by installing SIMM pairs in this additional bank:

- 2 MB, using four 1 Mbit x 4 DRAM soldered to the motherboard
- 4 MB, using two 1 Mbit SIMMs in the SIMM connectors
- 6 MB, using two 2 Mbit SIMMs in the SIMM connectors
- 10 MB, using two 4 Mbit SIMMs in the SIMM connectors

The Macintosh LC requires 100 ns or faster SIMMs.

Macintosh IIsi

The Macintosh IIsi is similar to the SE/30, II, IIX, and IICX in that it uses a 32-bit data bus with 8-bit SIMMs; you must always upgrade memory in four SIMM chunks. The IIsi differs in that it only has one SIMM bank instead of two (see Figure 4).

If future 16 Mbit DRAMs are compatible with the current refresh frequency, then the IIsi will support 16 Mbit SIMMs, enabling a RAM configuration of 65 MBs (4 x 16 MB + 1 MB). The IIsi requires 100 ns or faster SIMMs.

Macintosh IICI

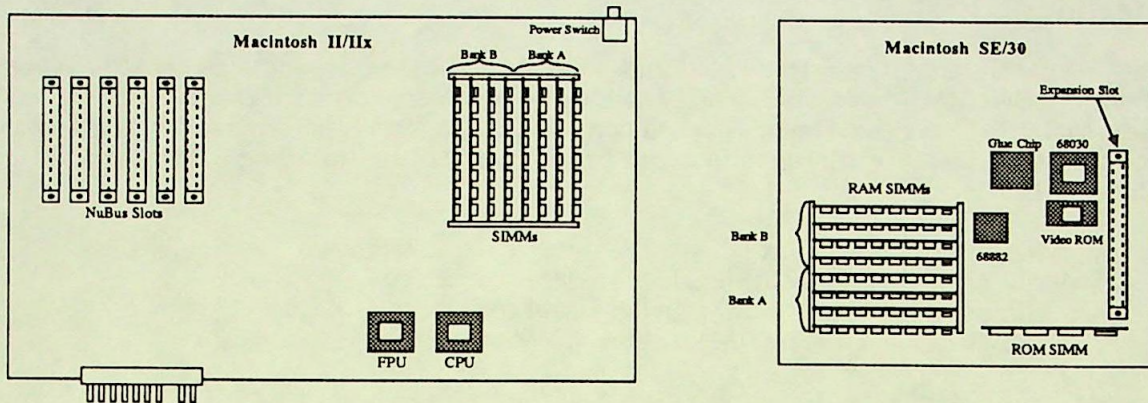
The Macintosh IICI motherboard layout is somewhat different from the IICX, but the location of the RAM SIMMs is unchanged. Bank A is still the bank closest to the disk drives. Refer to Figure 6 for the proper locations of Banks A and B on the IICI.

The IICI has a much-improved RAM interface and allows a great deal more freedom when installing SIMMs. Banks A and B are interchangeable, meaning that when mixing two sizes of RAM, the larger SIMMs do not necessarily have to go in Bank A. In fact, for best performance when using on-board video, Apple recommends that the smaller SIMMs be installed in Bank A. Note, however, that if on-board video is used, then RAM **must** be present in Bank A.

The IICI **requires** that SIMMs be 80 ns RAS-access time or faster and the same speed within a row. You can implement the following memory configurations with 256K and 1MB SIMMs:

- 1 MB using four 256 Kbit SIMMs in Bank A or in Bank B
- 2 MB using eight 256 Kbit SIMMs in Banks A and B
- 4 MB using four 1 Mbit SIMMs in Bank A or in Bank B
- 5 MB using four 256 Kbit SIMMs in Bank A and four 1 Mbit SIMMs in Bank B
- 5 MB using four 1 Mbit SIMMs in Bank A and four 256 Kbit SIMMs in Bank A
- 8 MB using eight 1 Mbit SIMMs in Banks A and B

The 1 MB and 4 MB configurations using only Bank B are not compatible with on-board video, since Bank A must contain memory when using on-board video. The first 5 MB configuration (with 256 Kbit SIMMs in Bank A) is recommended for 5 MB configurations using on-board video.



(SIMMs must be 120 nS RAS-access time or faster, and the same speed within a row.).

Macintosh II, IIx, and Macintosh SE/30 memory configurations are identical.

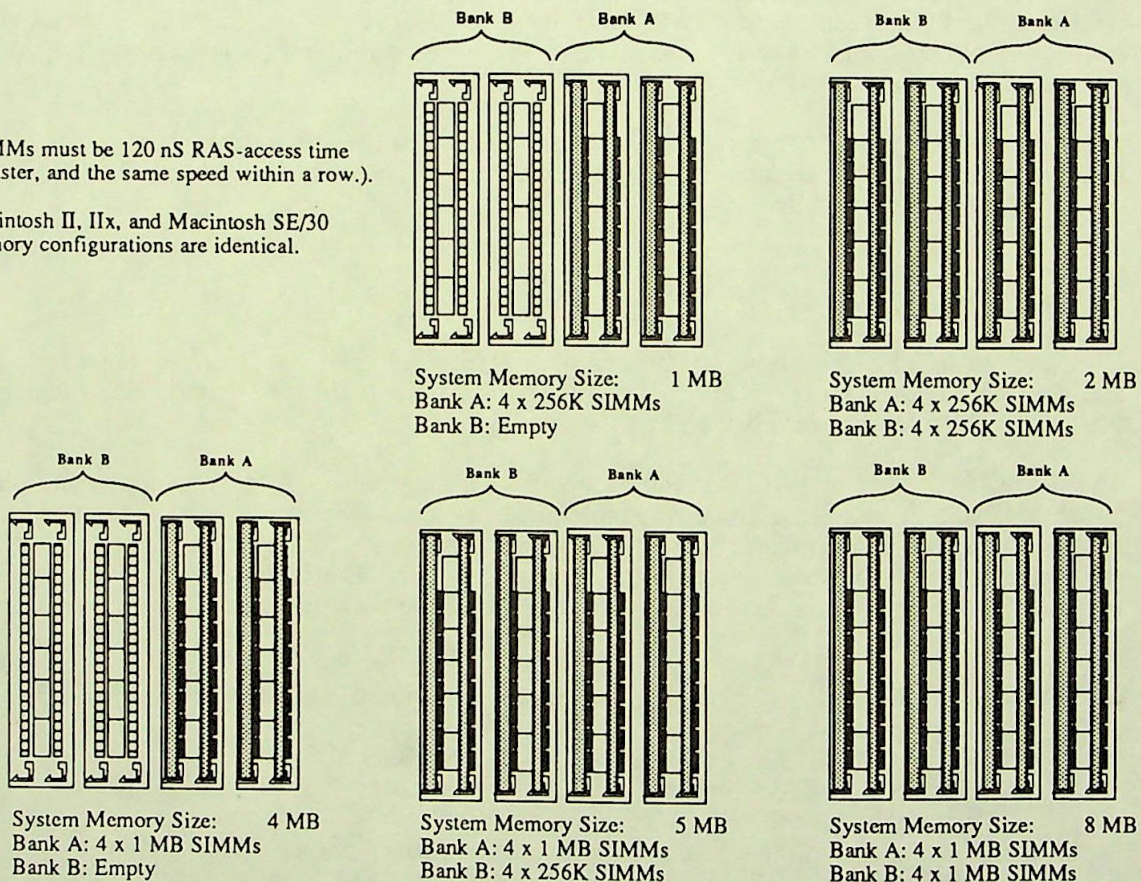


Figure 5—Macintosh SE/30, II, and IIx Memory Configurations

Parity RAM

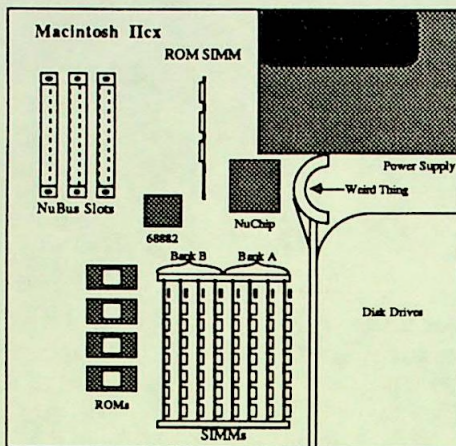
Some specially-ordered versions of the Macintosh IIci are equipped with a PGC chip and support parity for RAM error detection. These machines require parity RAM. SIMMs for these machines are nine bits wide instead of eight, so there is generally an extra RAM IC on the SIMM. There is no difference in the installation of 256K x 9 or 1M x 9 SIMMs.

Macintosh Portable

Memory expansion on the Macintosh Portable is different from other members of the Macintosh family since the Portable uses memory expansion cards in place of SIMMs. The base Portable is equipped with 1 MB of RAM on the motherboard and has one RAM expansion card slot. Apple currently supplies a 1 MB memory expansion kit which takes the Portable to 2 MB total. Apple and third-party developers may produce higher capacity expansion boards (2 MB to 8 MB) in the future.

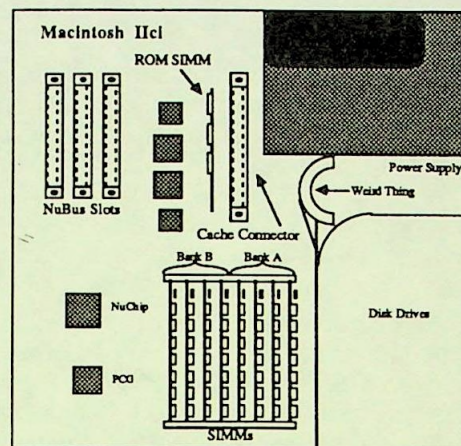
Since the Portable has only one RAM expansion slot, you may use only one memory expansion board at a time. This limit means that a 1 MB expansion board would have to be completely replaced by a higher capacity board when it became available.

Total RAM for the Portable will always be 1 MB plus the size of your one RAM expansion board (if installed). Refer to Figure 6 for the location of the RAM expansion slot.



(SIMMs must be 120 nS RAS-access time or faster, and the same speed within a row.)

Macintosh IIcx memory configurations are identical to the II, IIx, and SE/30.



(SIMMs must be 80 nS RAS-access time or faster, and the same speed within a row.)

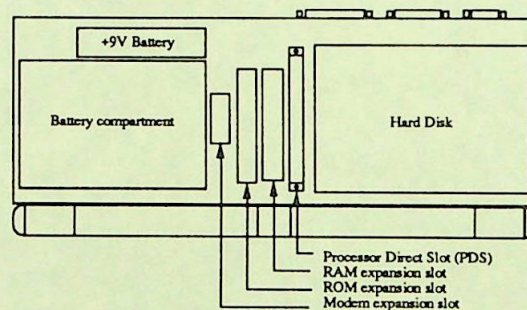


Figure 6—Macintosh IIcx, IIci, and Portable Memory Configurations

Macintosh IIfx

The Macintosh IIfx motherboard layout has its SIMMs located in the same general area as the IIfx, but they are oriented transversely. Bank A is the bank closest to the rear of the machine; bank B is closest to the main processor. Refer to Figure 7 for the proper memory bank locations.

The IIfx has a RAM SIMM interface similar to that of the IIfx, et al: when you are using a combination of SIMMs, the larger SIMMs (in terms of Mbits) must be in Bank A. When you are using only four SIMMs, they must be in Bank A as well. The description in the *Guide to the Macintosh Family Hardware*, Second Edition) inaccurately states the larger SIMMs can be placed in either bank.

The IIfx **requires** that SIMMs be 80 ns RAS-access time or faster and the same speed within a row. You can implement the following memory configurations with 1 and 4MB SIMMs (256K address-depth SIMMs are not supported):

- 4 MB using four 1 Mbit SIMMs in Bank A
- 8 MB using eight 1 Mbit SIMMs in Banks A and B
- 16 MB using four 4 Mbit SIMMs in Bank A
- 20 MB using four 4 Mbit SIMMs in Banks A and four 1 Mbit SIMMs in Bank B
- 32 MB using eight 4 Mbit SIMMs in Banks A and B

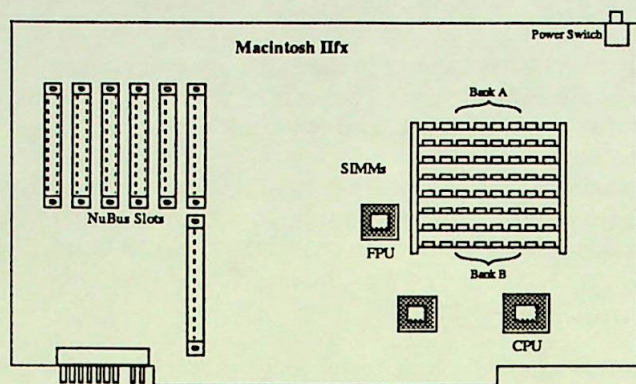
Parity RAM

Parity RAM requirements are as follows: if using 1 MB or 4 MB SIMMs, the RAM speed must be 60 ns. However, the parity circuit programmable array that goes on the motherboard as well as the parity PALs that go on the SIMMs are proprietary to Apple—their equations are not expected to be released to developers. Because of this proprietary design, Apple does not recommend third-party development of parity products.

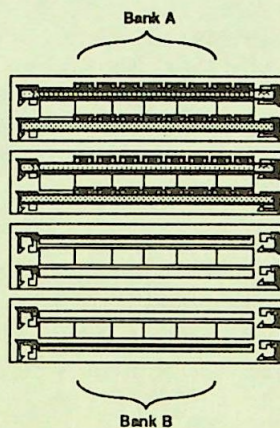
RAM SIMM drawings

The IIfx has 64-pin SIMMs, which are different from previous Macintosh models. Developers can request mechanical drawings and electrical specifications of the IIfx RAM SIMM modules from DTS. Please send the request with a mailing address and include the words “IIfx SIMM information request” in the title of the electronic mail request or letter to facilitate handling.

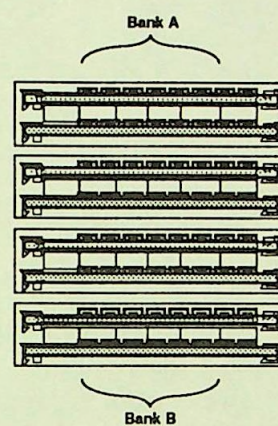
Warning: To avoid degradation of signal quality, it is critical to adhere to the strict timing parameters of the IIfx and to use a good layout which takes high-speed circuits into account.



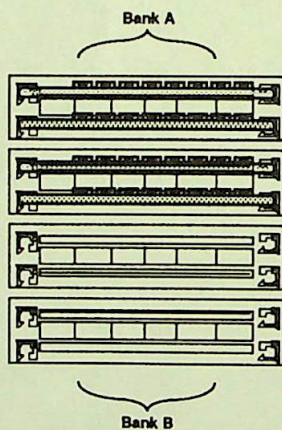
(SIMMs must be 80 nS RAS-access time or faster, and the same speed within a row).



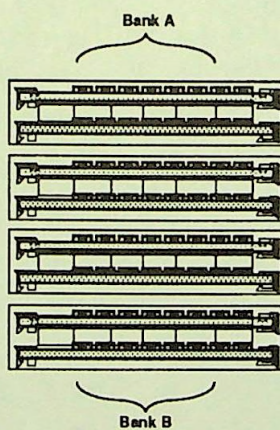
System Memory Size: 4 MB
Bank A: 4 x 1 MB SIMMs
Bank B: Empty



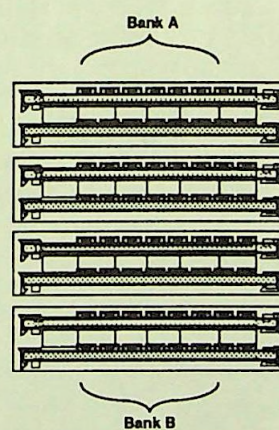
System Memory Size: 8 MB
Bank A: 4 x 1 MB SIMMs
Bank B: 4 x 1 MB SIMMs



System Memory Size: 16 MB
Bank A: 4 x 4 MB SIMMs
Bank B: Empty



System Memory Size: 20 MB
Bank A: 4 x 4 MB SIMMs
Bank B: 4 x 1 MB SIMMs



System Memory Size: 32 MB
Bank A: 4 x 4 MB SIMMs
Bank B: 4 x 4 MB SIMMs

Figure 7—Macintosh IIx Memory Configurations

4 Mbit DRAMs in Revolt

When the Macintosh II was originally designed, Apple engineers intended for it to accept large amounts of memory in the form of 4 MB and 16 MB DRAM SIMMs. That was in 1986, when 1 Mbit DRAM was difficult to find and the higher-density chips did not yet exist. The engineers anticipated the pinouts of the yet-to-be introduced 4 MB SIMMs and provided all the necessary hardware and address multiplexing to allow installation of these parts when they became available.

Woe that Cupertino is not Camelot, James Brown is in jail (well, work release), and 4 MB SIMMs do not work as advertised in most cases. This is the story of the Revolt of the 4 MB DRAM SIMMs.

Preliminary Notes

Before diving into the problem with 4 Mbit DRAMs, there is some preliminary ground which must be covered.

First, there are a couple ways to construct a 4 MB SIMM. Using old technology, it is possible to cram together 32 DRAM ICs of 1M x 1 density. Using new technology, it only takes eight 4M x 1 ICs, resulting in a much smaller, lower-power module. If a 4 MB SIMM is of the large, so-called composite type (i.e., it is constructed of thirty-two 1 Mbit ICs), then everything is fine **except** on the original Macintosh II.

This exception is due to an undocumented feature in the ROM firmware shipped with the original Macintosh II. Unfortunately, the original Macintosh II ROM startup code does not know about 4 MB SIMMs and dies a horrible death before the cursor even appears. Thus, a Macintosh II with original ROMs is limited to using 1 MB SIMMs and 8 MB RAM **maximum**. Subsequent Macintosh models have revised ROMs which recognize 4 MB SIMMs.

A Macintosh II CPU can receive a ROM upgrade enabling it to accept 4 MB SIMMs. This upgrade requires installation (strangely enough) of the 1.4 MB SuperDrive package. This requirement is presumably because the SuperDrive package includes the Macintosh IIfx ROMs, which can handle 4 MB SIMMs, but which also expect the presence of a SWIM chip in place of the old IWM.

With the SuperDrive upgrade, the Macintosh II is on equal footing with the Macintosh IIfx. That is, SIMMs made exclusively of the new 4 Mbit ICs still won't work, regardless of whether you are using a Macintosh II or IIfx; therefore, for the remainder of this discussion, Macintosh II is used to refer to not only the original Macintosh II, but also the IIfx.

The 4 Mbit Problem

DRAM ICs are now available in 4 Mbit density, but they come with a very nasty surprise. JEDEC, the committee overseeing the standardization of new solid-state devices, has added an additional built-in test mode to high-density DRAMs. The test mode is invoked by a sequence of electrical signals which was ignored by earlier-generation DRAM. The crux of the situation is this: under certain conditions, the Macintosh II unwittingly activates this new test mode and large amounts of memory become very forgetful.

More Specifically...

Those who are interested in the specific phenomenon occurring within the memory ICs should consult the detailed technical data supplied by the DRAM manufacturers. This Note only explains how the Macintosh II offends this new feature of the 4 Mbit DRAM, and hence, what might be done to work around the problem.

The Macintosh II uses /CAS-before-/RAS refresh cycles to keep RAM up-to-date on its contents. For 1 Mbit DRAM, the state of the /W control line is ignored during this type of refresh cycle. No longer. DRAM of the 4 Mbit variety goes off into test mode if /W is asserted (low, so that the RAM thinks it is write-enabled) during a /CAS-before-/RAS refresh cycle. The problem with the Macintosh II is that /W is the same signal as the MPU R/W line, and if the MPU is writing to an I/O address or a NuBus™ card concurrently with a refresh cycle, all the conditions are right for a waltz into test mode. Unfortunately, this condition is not all that unusual, since video card accesses qualify.

The Salvage Process

All is not necessarily lost, and although the situation is ugly, there is still a way to use 4 Mbit DRAM ICs to construct 4 MB SIMMs which work in the Macintosh II. A solution lies in the addition of a ninth IC to the SIMM. Programmed with suitable logic, a high-speed (-D or -E suffix) PAL™ on the SIMM itself can recognize and intercept /CAS-before-/RAS refresh cycles and set /W appropriately before any damage is done. More or less, the PAL becomes an intelligent buffer between the MPU read/write line and the DRAM write-enable lines. When the PAL senses a refresh cycle commencing, it holds /W high, ensuring that the ICs are not corrupted by the potentially dangerous processor-generated R/W signal.

What the Future Holds...

It is unlikely that Apple will recall the affected machines to install a fix or even change the design of current-model Macintosh II computers produced in the future. New members of the Macintosh family should correct the problem, however. Note that the Macintosh SE/30, IIfx, and IIfx all address this problem. There are currently no specifications available for 16 Mbit DRAM; therefore, it is unknown at this time whether any current Macintosh models will be compatible with these devices.

Consolation for SIMM manufacturers: SIMMs constructed with an on-board PAL are not necessarily Macintosh II-specific. SIMMs constructed in this manner should work without modification in any application calling for 4 MB SIMMs (except in the unlikely event an application requires the new test mode).

What's the Point?

You have overcome all the problems discussed in this section and have working 4 Mbit SIMMs installed in your Macintosh. You probably have at least 20 MB of RAM. What can you do with all of it? Create lots of huge 32-bit PICTs and edit them all simultaneously? Model and animate Bay Area weather patterns in Mathematica™? Sorry. Currently, there is no way to use more than 8 MB of RAM for standard Macintosh applications.

Special-purpose applications may always access and provide management for the extra RAM provided by 4 Mbit SIMMs, but there is no support for this prior to System 7.0. There is currently no standard for arbitration among various applications which may recognize and contend for use of memory beyond address \$0080 0000 in 32-bit mode. Competing applications could easily collide and crash.

Under System 7.0, applications can finally access the extra 12 MB of physical memory (in the hypothetical 20 MB system), but only using the 32-bit clean ROMs of the Macintosh IIci or later machines. A/UX is an alternative which supports any amount of RAM right now. Many manufacturers of 4 Mbit SIMMs offer RAM disks which put the extra memory to some good use, but the simple truth is that the extra RAM is not generally available today for transparent use by applications under the standard Macintosh operating system.

Further Reference:

- *Inside Macintosh*, Volume V-1, Compatibility Guidelines
- *Guide to the Macintosh Family Hardware*, Second Edition

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